Developing Algorithm Components for GPM Snowfall Retrievals

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Introduction The goal of this project is to develop algorithm components for snowfall detection and retrieval using GPM/GMI (as well as other microwave radiometers in the constellation) observations. Toward this goal, currently we are working on the following: (1) Develop a snow-rain separation algorithm using data of surface observations, (2) Develop scattering database and approximation method for aggregate snowflakes, (3) Develop an empirical snowfall detection/retrieval algorithm over land, and (4) Develop a snow cloud vs. brightness temperature database for snowfall over ocean.

Snow-Rain Separation

A snow-rain parameterization is developed using data:
Land: NCEP ADP Operational Global Surface Observations, 1997-2007
Ocean: International Comprehensive Ocean-Atmosphere Data Set (ICOADS), 1995-2007
Upper Air: Integrated Global Radiosonde Archive (IGRA)

Input variables:

- **Air temperature (2 m)**
- **Humidity (2 m)**
- **Low-level (0 - 500 m) lapse rate**
- **Surface skin temperature**
- **Land or ocean**

Output:

Probability of Solid Precipitation (Sims and Liu, 2015 JHM)

Scattering Database for Aggregates

Aggregate snowflakes have been created with their dimension-mass relation constrained by consensus of observations. Their scattering properties have been calculated using DDA and scattering table is archived on the web. With the addition of table to the earlier table for crystal type particles, we now have the scattering table for full range of ice/snow particles, with types of "rounded", "oblate" and "prolate" aggregates. (Liu, 2008; Nowell et al., 2013; Honeyager et al., 2015).

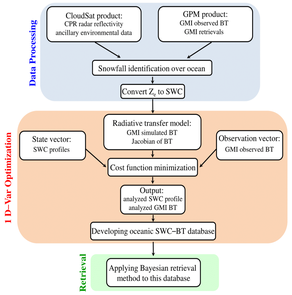
Conclusions

- Developed a pre-screening scheme to separate conditions of snow/rain, using environmental variables – T, q, Γ, etc.
- Continuing to improve/enhance snow scattering table
- Developed empirical snowfall retrieval algorithm based on radar-radiometer matchups
- Developed snow cloud – TB database for snow retrieval over ocean

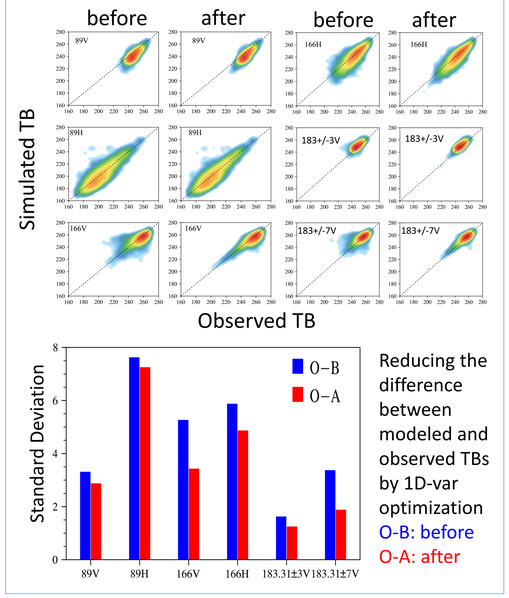
Development of Over Ocean Snow Cloud – Brightness Temperature Database

Approach: Over ocean, surface and atmospheric radiation can be better simulated. We explore the feasibility to build a physically consistent database relating brightness temperatures to snow cloud properties. The approach uses merged CloudSat, GPM, and reanalysis data.

It starts with snow water content (SWC) profiles derived from CloudSat CPR, uses a radiative transfer model and a 1D-Var optimization scheme to obtain a snow cloud properties – GMI TB database, which may be used for SWC/snowfall retrievals.

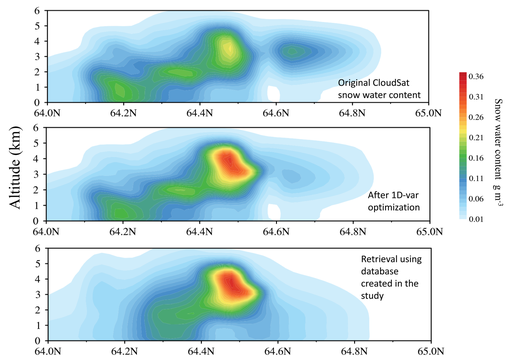


Before & After Optimization

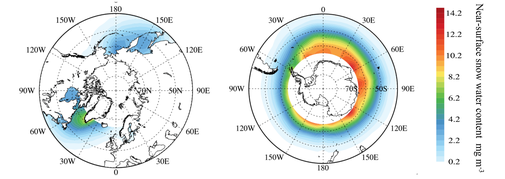


Reducing the difference between modeled and observed TBs by 1D-var optimization
O-B: before
O-A: after

Case on 12/11/2014

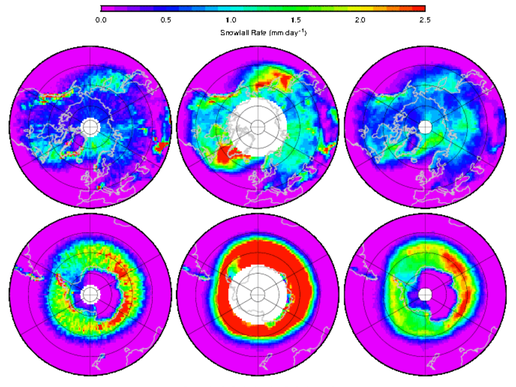


GMI-retrieved global SWC at near-surface level for 2015



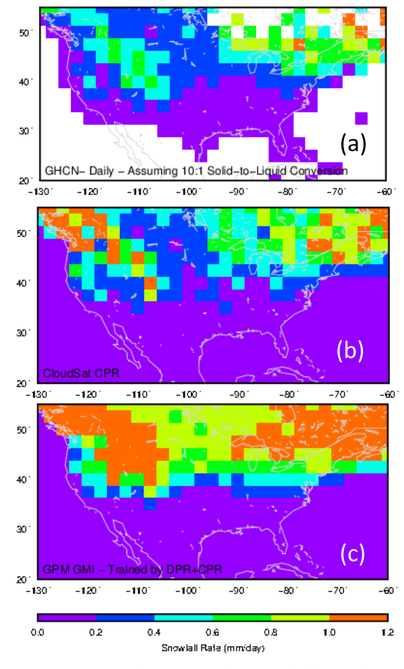
Empirical Snowfall Detection and Retrieval

Method: Over land, snowfall detection/retrieval is based on an empirical algorithm – lookup table using coincident MW radiometer and radar (DPR+CPR, as truth) data pairs. From radar reflectivity, first derive snowfall rate using a Z-S relation. Then a lookup table is generated that gives snowfall probability and snowfall rate in 3-D brightness temperature EOF space. (Liu&Seo, 2013)



CloudSat 2006-2010 | GMI 2014.4-2017.3 Trained by CPR+DPR | MHS 2006 -2016 Trained by CPR

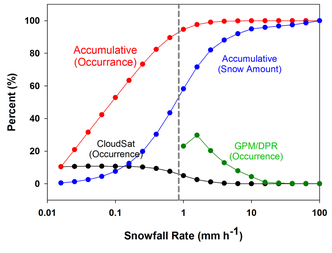
Mean snowfall rate maps retrieved from different sensors.
Left: CloudSat (Z-S).
Middle: GMI trained by CloudSat CPR & GPM/DPR;
Right: MHS trained by CloudSat CPR

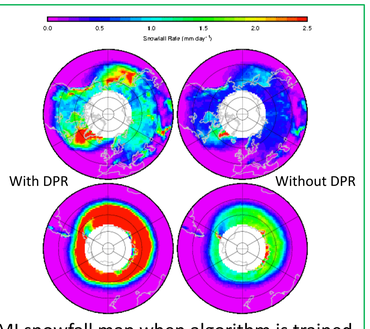


(a) GHCND + Canada Station observed climatology – multiple years
(b) CloudSat – near surface, 2006 – 2010.
(c) GMI – 2014.4-2017.3, trained by CloudSat/CPR + GPM/DPR
* Similar pattern – therefore, GMI is able to catch the snowfall signature
* Different magnitude – need more study for "truth" data, Z (radar) to S (snowfall) conversion.

Use combined CloudSat/CPR and GPM/DPR as "truth": DPR (Ku or Ka) has a minimum detection of about 13 dBZ, missing most of snowfall events, while CloudSat CPR has clear attenuations for heavy snowfall. Combined DPR-CPR data are used as "truth" in the GPM GMI empirical algorithm. Z-S relations for DPR/CPR are derived from scattering database with assumed size distributions.

Based on collocated CloudSat/CPR -GPM/DPR data: Mar. 2014 – Dec. 2015. Due to its low detectability, DPR may have missed about 50% of snowfall amount.





GMI snowfall map when algorithm is trained with (left, trained by CPR+DPR) and without (right, trained by CPR alone) DPR